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THE EFFECT UPON THE DEFLECTION PATTERN OF RESTRAINING THE LOWER CORNERS OF A PLATE THAT IS SIMPLY SUPPORTED ON THREE EDGES AND SUBJECTED TO A HYDROSTATIC LOADING

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THE EFFECT UPON THE DEFLECTION PATTERN OF RESTRAINING THE LOWER CORNERS OF A PLATE THAT IS SIMPLY SUPPORTED ON THREE EDGES AND SUBJECTED TO A HYDROSTATIC LOADING

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Admiral Lewis B. Coombs CEC USN ret, Head of the Civil Engineering Department, Rensselaer Polytechnic Institute, Troy, New York

for without their assistance the completion of this work would not have been possible.

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INTRODUCTION

Of primary importance in the maintenance of an effective fighting fleet is the graving dock. It is these docks that the major repairs are performed on many of the ships of the Navy.

The entrance closure is an integral part of a basin typedock, and the two factors governing its design are mobility and strength. It must be mobile to allow easy handling in clearing a channel for the ships to be floated in and out of the dock. Yet at the same time it must have sufficient strength to withstand the hydrostatic pressure of the water on the harbor side of the gate after the interior of the dock has been pumped dry. Of the several types that have proven satisfactory, the United States Navy favors the floating type of dry dock closure.

As is evidenced by the word caisson, this type of closure is essentially a box consisting of interior framing and an enveloping skin plating. When this type of closure is in position it rests on the support edges of the dock and is held tightly in place by the hydrostatic pressure of the water outside of the dock.

The design of the caisson is a particular

problem faced by the design staff of the Bureau of Yards and Docks. Because design of graving docks and their appurtenances are a special case, it is a subject that is not covered in regular courses at a university. Information regarding this subject can be found only with those people who are working along these lines.

Recently the Bureau has developed a new method of an analysis of the caisson design problem, that is assuming the entire caisson to act as a rectangular slab. Design formulas based on this assumption have been developed by Mr. A. Amerikian of the Bureau on a theoretical basis.

The tests in this experiment simulate dry dock caisson reactions in that the test specimens are slabs and they are subjected to similar types of loading.

This thesis deals with the determination of the deflections of a plexiglas plate test specimen that is simply supported on three sides and subjected to a hydrostatic load. Each specimen undergoes two particular tests, first with the lower corners of the specimen unrestrained; secondly with the lower corners restrained. Particular attention is paid to the difference between the deflection patterns and the magnitudes of deflection caused by the restraint of the lower corners.

OBJECT

The object of this thesis is to determine with reasonable accuracy information relative to an analysis of a rectangular slab simply supported on three sides and subjected to hydrostatic loading made by Mr. A. Amerikian. This analysis has been found to give satisfactory results but has been lacking experimental verification. The experimental information herein presented is the measurement of deflections at various points in the specimen fulfilling the basic conditions of the analysis, that is:

a) No deflection at the three supports

b) No moment along the three supports

c) Transverse moment at the unsupported edge is zero

d) Reaction at the unsupported edge is zero.

A P P A R A T U S

The primary piece of apparatus used in this test was a welded steel tank, three feet in length, one foot wide and one foot deep. The ends, bottom and one side of the tank consisted of one-eigth steel plate and the front side of the tank was one-half steel plate being made of heavier section because it served as a basis for all measurements and necessitated possession of a smooth surface as well as adequate resistance to any tendency to warp. Hereafter this one-half inch plate will be referred to as the reference plate.

In this reference plate at a distance of one inch center to center in both vertical and horizontal directions holes were drilled through the plate to serve as a basic grid system for all measurements.

Attached to the inner surface of the reference plate were steel knife edges machined to a uniform depth and width which served as the supports for the test specimen.

All readings were made with the use of a depth micrometer with a least count of one thousandth of an inch.

Test specimens were acrylic plastic that is sold under the trade name of Plexiglas. There were two test

specimens, one one-half inch and one three-eigths inch. The modulus of elasticity of Plexiglas is 4.0×10^5 to 5.0×10^5 psi and Poisson's Ratio is 0.33 to 0.35.

PROCEDURE

The tank was set up adjacent to the water supply and carefully leveled to insure that the hydrostatic load be level across the top of the tank. Once the tank had been positioned properly the test specimen was placed in position against the knife edges.

At this point it might be well to mention that considerable difficulty was encountered in securing a waterproof joint between the Plexiglas and the knife edges. It was finally found after many trials that the most efficient method of securing a good joint was to tape it. Therefore a plastic membrane and waterproof tape were used in such a way as to provide no hinderence to the movement of the plate under load.

Once the plate was positioned and the joint prepared to satisfaction the tank was filled slowly until the water level in the tank reached the level of the top of the test specimen. The load was carefully maintained throughout the entire test.

This same procedure was repeated three times for each specimen during each phase of the test. The deflections of the plate were measured by means of a depth micrometer to the accuracy of one one-thousandth of an inch and the mean of three readings recorded.

To provide a restraining action to the lower corners of the test specimen the main tank was equiped with small steel flanges that were bolted to the bottom of the tank. Through these flanges a set screw was positioned so that the axis of the set screw coincided with the intersection of the edges of the vertical and horizontal knife edges. The set screws themselves were two inches in length and when they were tightened they provided ample restraining effect to the lower corners of the plate. Care was taken to insure that the point of the screw met the test plate at the exact spot opposite the knife edges because restraint at any other point would introduce moment into the plate thus throwing off the deflections caused by the hydrostatic loading.

This same procedure was followed with each thickness of test specimen and the mean of three individual readingsrecorded.

The holes in the reference plate totaled three hundred eighty-five in number which necessitated some logical method of notation. The horizontal rows (columns) consisted of thirty-five holes and in the vertical direction (rows) there were eleven holes. Therefore starting with the hole in the upper left hand corner of the reference plate, the holes are numbered

consecutively from left to right and from top to bottom respectively. In all readings the vertical coordinate is given first and then the horizontal coordinate. For example a point would be numbered 11-30, 9-16, or 1-3.

Curves of the deflection along the horizontal, along the vertical, and a contour of the plate to the interval of twenty-five thousandths of an inch were plotted.

All data are placed in the form of tables with the vertical coordinates across the top of the chart and the horizontal coordinates along the side.

There was no way to determine whether the plane of the knife edges was parallel to the plane of the reference plate. To eliminate any difficulty that might result from this uncertainity readings were taken of the plate when there was no load. These readings gave an accurate starting point for all successive readings. The difference between the zero reading and the reading recorded under load conditions would be the actual deflection of the plate at that point.

RESULTS

The results of the several investigations are shown in the form of plotted curves so that the clearest view may be readily ascertained. These curves show vertical and horizontal sections along lines of the plate spaced at two inch intervals. Also to bring out the dishing effect created by the hydroatatic loading, contours at .025" interval are also included. With the lower corners free, it was found that these corners bent away from the support. By finding the intersection of the zero contour with the knife edge, the limit of contact was established with far more accuracy than any other means possible using the plate and tank as set up. Then finally the comparison of deflections of the plate with restrained and unrestrained lower corners is made.

It is obvious that only one half the plate width has beenconsidered in obtaining measurements and for plotting purposes. Preliminary inquiry with the apparatus and plates indicated symmetrical deflections within reasonable limitations occurred as should be expected and nothing could be gained over operation with one half plate width.

IRREGULARITIES

There are several factors which will vary the deflection of plexiglas and in some cases more so than with other materials. These variations are not herein presented since only the mean of several readings are included, but during the course of investigation small irregularities were observed. In some instances such as temperature and rate of loading the variations are due directly to the composition of the material.

The effect of temperature had probably the least effect since the observations were all made at water temperature and it underwent little change.

There was no control over the rate of loading and therefore its effect could not be described. References however, did indicate that for small loads used in these experiments the effect should be minor.

The plexiglas plates were guaranteed to have a thickness tolerance of plus or minus one one-hundredth of an inch maximum, a characteristic over which there was no control while measurements were made. The fact that zero readings were made may have minimized the effect of thickness variation or on the other hand just as easily increased the regularity of readings.

Lastly there is always the human error which

itself in this type of work. In an attempt to maintain control of it each author made at least one set of readings so that a better verification could be made. Thus it is hoped that the mean og the readings will tend to cancel the error of the individual readings.

DISCUSSION

The results clearly indicate that restraining the lower corners affects the deflections of the rectangular slab.

It was unfortunate that no conception of the magnitude of deflection was known beforehand, and also that it was beyond the ability of the authors to compute such deflections before experimentation was begun. It was intended to make similar tests on thinner plates. The apparatus could not facilitate them without a change in set-up and due to the short time for conducting the experiments changes were not possible. It was impossible to load a one quarter inch plate to a head of one foot since the deflections were so large that the plate rested on the back of the reference plate.

It has been found by this experiment that when the lower corners are unrestrained, they pull away from the supports under the hydrostatic load. This fact makes one wonder what happens when an actual caisson is subjected to loading? It is not possible for a negative reaction to exist and yet the graving dock remains dry when the caisson has been floated into place and the dock pumped dry. Are the actual dimensions such

that this movement away from the support is negligible?

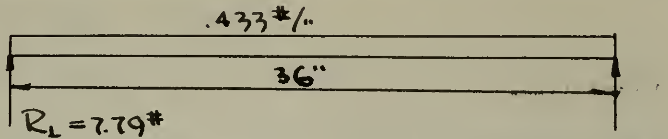
Also in the analysis cosidering a negative reaction to exist, the design of the structure can be made accordingly. Without this reaction the deflections are larger but caisson failures are few and the analysis has been proved sufficient. It is unfortunate that this work can not answer these questions; since it was intended to be a means of verification of the present analysis.

There are two other points which could be sources of error, the plastic seal and possible plastic deformation. In regards to the plastic seal, knowledge gained after completion of the work of the authors, is that the Englishhave worked with similar seals. They have found that even with the utmost care it is impossible to keep a small amount of reaction from going through the plastic cloth and to the sides of the tank thus never reaching the supports for the plate. From information available they have not determined the magnitude of this loss. In fact, at present Messr's Cahn and Atwater of the CEC are working in an endeavor to find the reactions as distributed to the supports.

Plexiglas was used for these experiments since it would give appreciable deflections under conditions of loading. It can not be stated conclusively that there

was no plastic deformation but the following calculation will show that it seems highlt improbable.

Assuming the lower inch of the three-eigths specimen is subjected to a one foot head of water as a load and is supported as a simple beam, the compressive stress at the outer fibers can be found.



$$M_{CL} = 7.79 \times 18 - .433 \times \frac{18^2}{2} = 70''\#$$

$$S = \frac{Mc}{I} = \frac{70 \times .375 \times 12}{1 \times .187^3} = 4810 \text{ psi}$$

At a temperature of 68 deg. F. it takes a stress of 8600 psi 1000 minutes to produce a ten per cent plastic deformation under compressive stress. In making observations the material was never kept under load longer than one hour; so that it is hardly probable plastic deformation had any effect.

CONCLUSIONS

The results herein presented can only show the effect of the lower corner restraint. It is intended that Mr. A. Amerikian and his staff will utilize this data to verify or improve the existing analysis as used for design purposes.

In the event that it is desired to carry this work further ahead, there are certain modifications which could be suggested. Another means of reading could be used so that all the reaction goes into the supports and at the same time the overhang of the plate beyond the knife edge eliminated. This overhang is sufficient to cause a small moment which decreases the moment at the points where deflections are measured.

The tank arrangement could be improved so that the plane of knife edges would be parallel to the reference plane. Of course an alternate set-up could be arranged for measuring so that the use of refenence plate is eliminated.

The use of other materials as thin aluminum sheet with better thickness tolerances. Use of aluminum may create less deflection than plexiglas so that it may be necessary to support the plate horizontally and use sand as a loading medium. Though differing from actual caisson conditions this may be a more accurate means of verification

ZERO READINGS

	1	2	3	4	5	6	7	8	9	10	11
1	.436	.430	.425	.420	.415	.412	.414	.413	.413	.414	.419
2	.444	.436	.433	.429	.424	.417	.413	.413	.414	.412	.415
3	.452	.445	.437	.431	.426	.421	.417	.415	.413	.409	.412
4	.456	.449	.444	.439	.431	.426	.421	.417	.412	.407	.410
5	.456	.449	.444	.436	.432	.426	.420	.416	.412	.408	.410
6	.456	.450	.445	.433	.434	.426	.419	.415	.411	.409	.410
7	.457	.451	.445	.437	.434	.426	.420	.416	.411	.409	.408
8	.458	.452	.444	.442	.434	.425	.422	.416	.412	.409	.407
9	.457	.451	.444	.436	.430	.423	.419	.411	.408	.407	.406
10	.457	.450	.444	.431	.427	.420	.416	.407	.405	.405	.404
11	.455	.448	.444	.431	.425	.418	.414	.407	.406	.406	.403
12	.452	.447	.445	.432	.423	.416	.413	.407	.408	.406	.402
13	.451	.445	.441	.431	.422	.415	.414	.408	.407	.404	.404
14	.450	.443	.437	.430	.422	.414	.414	.409	.406	.401	.404
15	.451	.443	.437	.430	.423	.417	.414	.411	.406	.403	.402
16	.452	.443	.438	.431	.425	.419	.414	.413	.407	.404	.403
17	.454	.447	.439	.431	.425	.421	.414	.414	.409	.403	.404
18	.457	.450	.440	.431	.425	.424	.415	.415	.410	.403	.406

**** NOTE: Due to space limitations of paper in all the following tables vertical rows of the reference plate are shown horizontally numbered 1 to 11 and the columns vertically as 1 to 18. Also for the same reason the tables of zero and of the actual distance from the reference plate to the specimen measurements are shown as being less than one inch where in reality they are greater than one inch; for example 1-1 was measured as 1.436" but is is recorded here as being .436". The data in the deflection tables is the actual deflection.

3/8 PLATE UNRESTRAINED

Plate to Specimen

	1	2	3	4	5	6	7	8	9	10	11
1	.427	.416	.411	.407	.406	.406	.411	.417	.426	.436	.461
2	.396	.396	.397	.395	.393	.391	.397	.406	.416	.431	.447
3	.365	.364	.369	.371	.371	.377	.380	.393	.402	.417	.433
4	.334	.332	.341	.346	.350	.362	.363	.375	.389	.402	.420
5	.303	.303	.313	.320	.328	.340	.348	.362	.377	.392	.409
6	.272	.275	.285	.296	.306	.317	.330	.351	.365	.382	.399
7	.239	.249	.259	.272	.284	.300	.316	.336	.353	.373	.392
8	.207	.222	.233	.249	.263	.280	.301	.317	.342	.363	.390
9	.181	.198	.211	.230	.247	.266	.287	.311	.335	.357	.393
10	.154	.174	.190	.210	.232	.251	.274	.303	.327	.353	.385
11	.139	.153	.172	.193	.216	.238	.267	.294	.325	.351	.390
12	.105	.130	.154	.176	.201	.224	.257	.286	.321	.347	.378
13	.092	.119	.143	.167	.193	.218	.255	.282	.316	.344	.378
14	.080	.108	.133	.158	.186	.212	.251	.278	.310	.341	.380
15	.074	.099	.126	.252	.181	.208	.246	.274	.308	.340	.376
16	.066	.093	.119	.147	.176	.207	.241	.273	.308	.341	.377
17	.057	.084	.109	.139	.169	.201	.234	.271	.305	.339	.380
18	.048	.075	.099	.133	.163	.196	.227	.265	.303	.336	.374

Specimen Deflection

	1	2	3	4	5	6	7	8	9	10	11
1	.011	.014	.014	.013	.009	.006	.003	-.004	-.013	-.022	-.042
2	.048	.040	.036	.034	.031	.026	.016	.007	-.002	-.019	-.032
3	.085	.078	.064	.055	.045	.037	.023	.010	-.007	-.021	-.023
4	.122	.117	.103	.093	.081	.064	.058	.042	.023	.005	-.010
5	.153	.146	.131	.115	.105	.090	.075	.055,	.037	.016	.001
6	.184	.175	.160	.137	.128	.109	.089	.064	.046	.027	.011
7	.218	.203	.185	.165	.150	.128	.107	.083	.060	.038	.015
8	.251	.230	.211	.193	.171	.145	.121	.099	.070	.046	.017
9	.275	.253	.233	.207	.187	.159	.132	.102	.075	.050	.013
10	.303	.276	.254	.221	.195	.169	.142	.104	.078	.052	.019
11	.324	.295	.272	.238	.213	.180	.148	.114	.083	.055	.013
12	.347	.317	.291	.256	.222	.192	.156	.121	.087	.059	.024
13	.358	.325	.297	.264	.230	.195	.160	.227	.092	.059	.026
14	.370	.335	.304	.272	.236	.212	.163	.131	.096	.060	.024
15	.379	.342	.311	.279	.240	.208	.164	.134	.095	.061	.026
16	.387	.350	.319	.284	.249	.212	.163	.140	.099	.063	.026
17	.397	.363	.330	.291	.252	.219	.178	.145	.100	.062	.024
18	.409	.375	.341	.298	.262	.228	.188	.150	.107	.067	.032

3/8 PLATE RESTRAINED

Plate to Specimen

	1	2	3	4	5	6	7	8	9	10	11
1	.431	.421	.417	.418	.412	.407	.406	.406	.405	.405	.410
2	.410	.409	.403	.401	.402	.401	.400	.401	.403	.406	.412
3	.384	.382	.383	.381	.382	.388	.386	.393	.395	.399	.406
4	.358	.356	.364	.362	.375	.372	.385	.387	.391	.393	.406
5	.334	.333	.341	.344	.347	.358	.360	.371	.380	.386	.397
6	.309	.311	.318	.326	.332	.340	.348	.357	.374	.382	.393
7	.282	.288	.296	.292	.313	.326	.338	.352	.368	.377	.391
8	.255	.265	.274	.277	.294	.311	.325	.337	.352	.369	.390
9	.233	.245	.256	.264	.282	.304	.322	.348	.365	.378	.388
10	.212	.225	.239	.252	.270	.298	.320	.347	.363	.383	.384
11	.195	.205	.225	.241	.256	.278	.304	.329	.339	.371	.385
12	.178	.192	.212	.230	.243	.263	.290	.311	.336	.359	.382
13	.162	.182	.200	.219	.236	.259	.285	.306	.332	.355	.381
14	.147	.170	.188	.208	.229	.257	.278	.301	.328	.352	.384
15	.140	.164	.183	.202	.224	.253	.275	.299	.327	.351	.385
16	.134	.157	.177	.196	.222	.249	.272	.298	.326	.353	.384
17	.130	.155	.174	.198	.220	.247	.271	.298	.325	.351	.384
18	.127	.153	.171	.198	.218	.246	.269	.298	.325	.349	.381

Specimen Deflection

	1	2	3	4	5	6	7	8	9	10	11
1	.005	.009	.008	.002	.003	.005	.008	.007	.008	.009	.009
2	.034	.027	.030	.028	.022	.016	.013	.012	.011	.006	.003
3	.068	.063	.061	.058	.049	.038	.035	.024	.017	.009	.006
4	.098	.093	.080	.077	.069	.051	.049	.032	.025	.016	.008
5	.122	.117	.103	.092	.085	.068	.060	.045	.032	.022	.013
6	.147	.139	.127	.111	.102	.086	.071	.058	.037	.027	.017
7	.175	.163	.149	.145	.121	.100	.082	.064	.043	.032	.017
8	.203	.187	.170	.165	.140	.114	.097	.089	.060	.040	.017
9	.224	.206	.188	.172	.148	.119	.097	.063	.043	.037	.018
10	.245	.225	.205	.179	.157	.133	.096	.060	.042	.022	.020
11	.257	.242	.220	.191	.167	.148	.109	.088	.069	.035	.021
12	.274	.255	.233	.202	.180	.154	.123	.096	.072	.047	.020
13	.289	.263	.241	.214	.186	.156	.129	.102	.075	.049	.023
14	.303	.273	.259	.222	.193	.157	.136	.108	.078	.049	.020
15	.311	.279	.254	.228	.199	.164	.139	.112	.083	.052	.018
16	.318	.286	.261	.235	.203	.170	.142	.115	.081	.051	.019
17	.324	.292	.265	.233	.205	.174	.143	.116	.084	.052	.020
18	.330	.297	.269	.233	.207	.198	.146	.117	.085	.054	.025

1/2 PLATE UNRESTRAINED

Plate to Specimen

	1	2	3	4	5	6	7	8	9	10	11
1	.428	.428	.418	.415	.410	.413	.413	.417	.427	.436	.439
2	.420	.412	.411	.407	.407	.407	.410	.409	.417	.424	.435
3	.411	.407	.402	.397	.395	.396	.399	.403	.408	.414	.425
4	.396	.393	.392	.390	.389	.390	.389	.397	.400	.404	.417
5	.382	.383	.380	.384	.379	.383	.382	.389	.393	.400	.410
6	.369	.368	.368	.372	.372	.374	.378	.381	.388	.397	.396
7	.355	.355	.357	.361	.363	.365	.369	.375	.382	.391	.402
8	.342	.342	.346	.348	.354	.357	.363	.366	.377	.385	.399
9	.329	.330	.335	.337	.344	.346	.355	.363	.372	.380	.396
10	.315	.318	.324	.325	.334	.337	.348	.359	.368	.378	.392
11	.305	.307	.315	.318	.326	.334	.345	.353	.365	.376	.392
12	.295	.295	.306	.312	.318	.329	.340	.347	.364	.374	.393
13	.283	.288	.299	.306	.312	.320	.335	.345	.358	.373	.391
14	.272	.282	.293	.300	.307	.314	.330	.343	.351	.369	.388
15	.270	.278	.287	.297	.307	.314	.330	.343	.351	.372	.388
16	.268	.273	.281	.292	.305	.315	.326	.342	.355	.372	.391
17	.265	.274	.280	.291	.298	.308	.324	.341	.356	.370	.389
18	.262	.276	.286	.290	.297	.304	.323	.340	.356	.367	.387

Specimen Deflection

	1	2	3	4	5	6	7	8	9	10	11
1	.008	.002	.007	.005	.005	-.001	.001	-.004	-.014	-.022	-.022
2	.024	.024	.022	.022	.017	.010	.003	.004	-.003	-.012	-.020
3	.041	.038	.035	.034	.031	.025	.018	.012	.005	-.006	-.013
4	.060	.056	.052	.049	.042	.036	.032	.020	.012	.003	-.007
5	.074	.067	.064	.053	.052	.039	.038	.027	.019	.008	.000
6	.087	.083	.077	.061	.062	.052	.041	.034	.023	.012	.012
7	.107	.096	.088	.076	.071	.061	.051	.041	.029	.018	.007
8	.116	.110	.098	.094	.080	.068	.059	.050	.035	.024	.008
9	.128	.121	.109	.099	.086	.077	.064	.048	.036	.027	.010
10	.143	.132	.120	.106	.093	.083	.068	.048	.037	.027	.012
11	.150	.141	.129	.113	.099	.084	.069	.054	.041	.036	.011
12	.157	.152	.139	.120	.105	.087	.073	.060	.044	.032	.009
13	.168	.157	.142	.137	.110	.095	.079	.063	.049	.031	.013
14	.178	.161	.144	.130	.115	.100	.084	.066	.055	.032	.016
15	.181	.165	.150	.133	.116	.103	.091	.069	.052	.044	.014
16	.184	.170	.157	.139	.120	.104	.088	.071	.052	.032	.012
17	.189	.173	.159	.140	.127	.113	.090	.073	.053	.034	.015
18	.195	.174	.154	.141	.128	.120	.092	.075	.054	.036	.020

1/2 PLATE RESTRAINED

Plate to Specimen

	1	2	3	4	5	6	7	8	9	10	11
1	.427	.425	.420	.415	.411	.409	.407	.405	.403	.402	.405
2	.429	.426	.421	.416	.413	.410	.405	.404	.403	.399	.403
3	.419	.419	.414	.409	.406	.407	.399	.399	.398	.398	.403
4	.410	.412	.406	.403	.400	.402	.396	.395	.394	.393	.401
5	.403	.401	.398	.394	.393	.394	.391	.393	.392	.394	.402
6	.391	.391	.388	.386	.387	.386	.387	.387	.393	.394	.399
7	.383	.380	.378	.379	.380	.382	.382	.382	.388	.393	.398
8	.368	.368	.371	.372	.374	.376	.379	.384	.393	.399	.399
9	.356	.359	.361	.363	.367	.369	.372	.374	.380	.390	.398
10	.347	.351	.355	.352	.361	.361	.366	.369	.377	.389	.399
11	.336	.340	.344	.344	.350	.353	.360	.365	.373	.379	.399
12	.325	.329	.333	.366	.339	.345	.354	.362	.369	.376	.395
13	.315	.319	.325	.328	.333	.344	.351	.357	.365	.373	.393
14	.305	.310	.317	.320	.327	.341	.349	.354	.360	.373	.391
15	.302	.309	.314	.319	.325	.337	.345	.353	.361	.373	.393
16	.298	.307	.311	.316	.323	.333	.341	.352	.364	.373	.393
17	.296	.307	.310	.314	.320	.330	.340	.351	.363	.373	.393
18	.294	.305	.309	.314	.318	.330	.337	.350	.364	.374	.394

Specimen Deflection

	1	2	3	4	5	6	7	8	9	10	11
1	.009	.005	.005	.005	.004	.003	.007	.008	.010	.012	.014
2	.015	.010	.012	.013	.011	.007	.008	.009	.011	.013	.012
3	.033	.026	.023	.022	.020	.014	.018	.016	.015	.010	.009
4	.046	.037	.038	.036	.031	.024	.025	.022	.018	.014	.009
5	.053	.048	.046	.045	.046	.037	.035	.028	.020	.013	.008
6	.065	.059	.057	.047	.047	.040	.032	.028	.018	.015	.011
7	.074	.071	.067	.058	.054	.044	.039	.034	.033	.016	.010
8	.090	.084	.073	.070	.060	.049	.043	.037	.028	.016	.008
9	.101	.093	.083	.079	.063	.054	.047	.037	.028	.017	.008
10	.110	.099	.089	.079	.066	.059	.050	.039	.038	.016	.005
11	.119	.108	.100	.087	.075	.065	.054	.042	.033	.027	.011
12	.127	.118	.112	.096	.084	.071	.059	.045	.039	.030	.007
13	.136	.126	.116	.103	.089	.071	.063	.051	.042	.031	.011
14	.145	.133	.120	.110	.095	.073	.065	.055	.046	.028	.013
15	.149	.134	.23	.111	.098	.080	.069	.058	.045	.030	.009
16	.154	.136	.127	.115	.102	.086	.073	.061	.043	.031	.010
17	.158	.140	.129	.117	.105	.091	.074	.063	.046	.030	.011
18	.164	.145	.131	.126	.113	.094	.078	.065	.046	.039	.012

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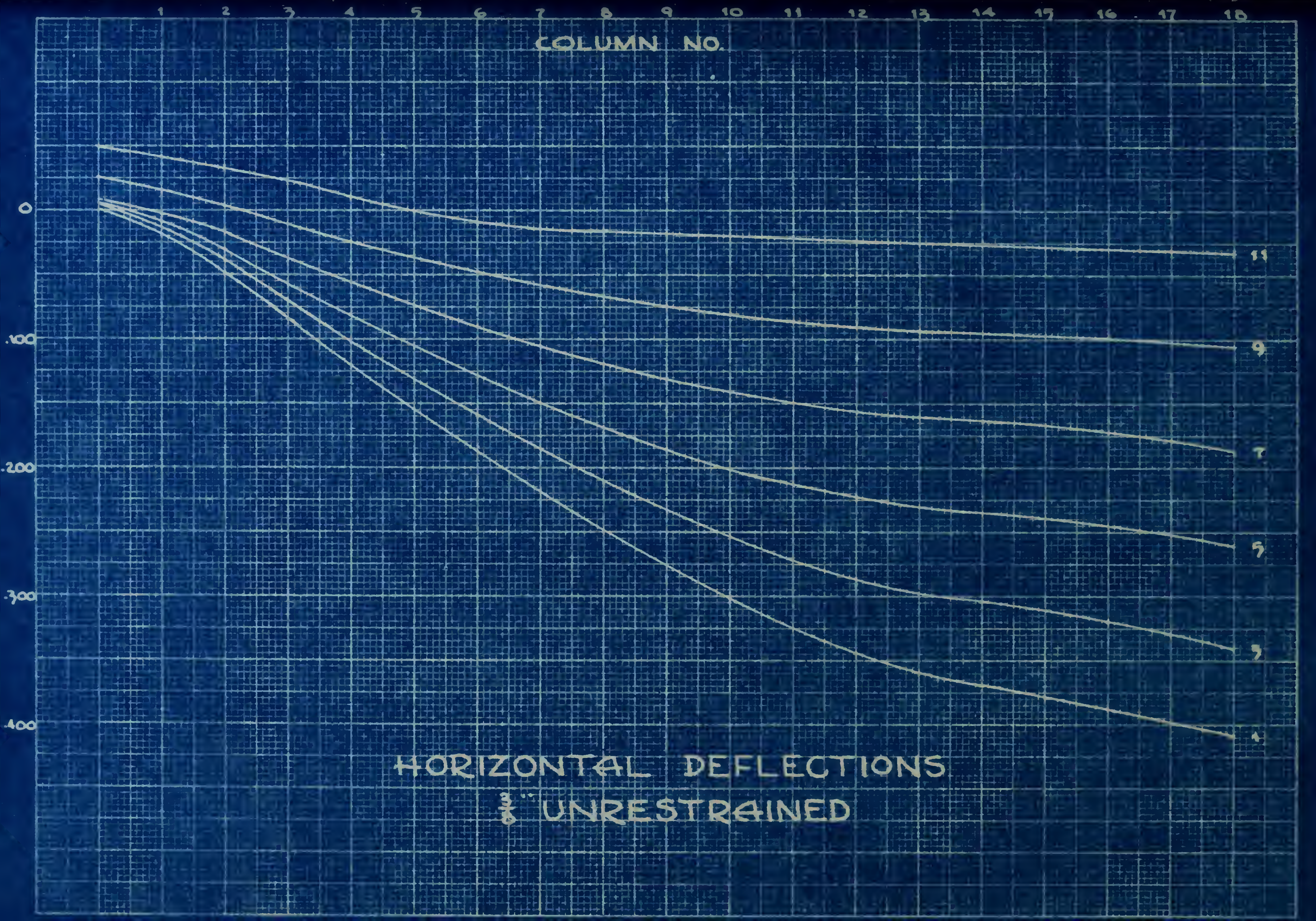
Principal Engineer, Bureau of Yards and Docks



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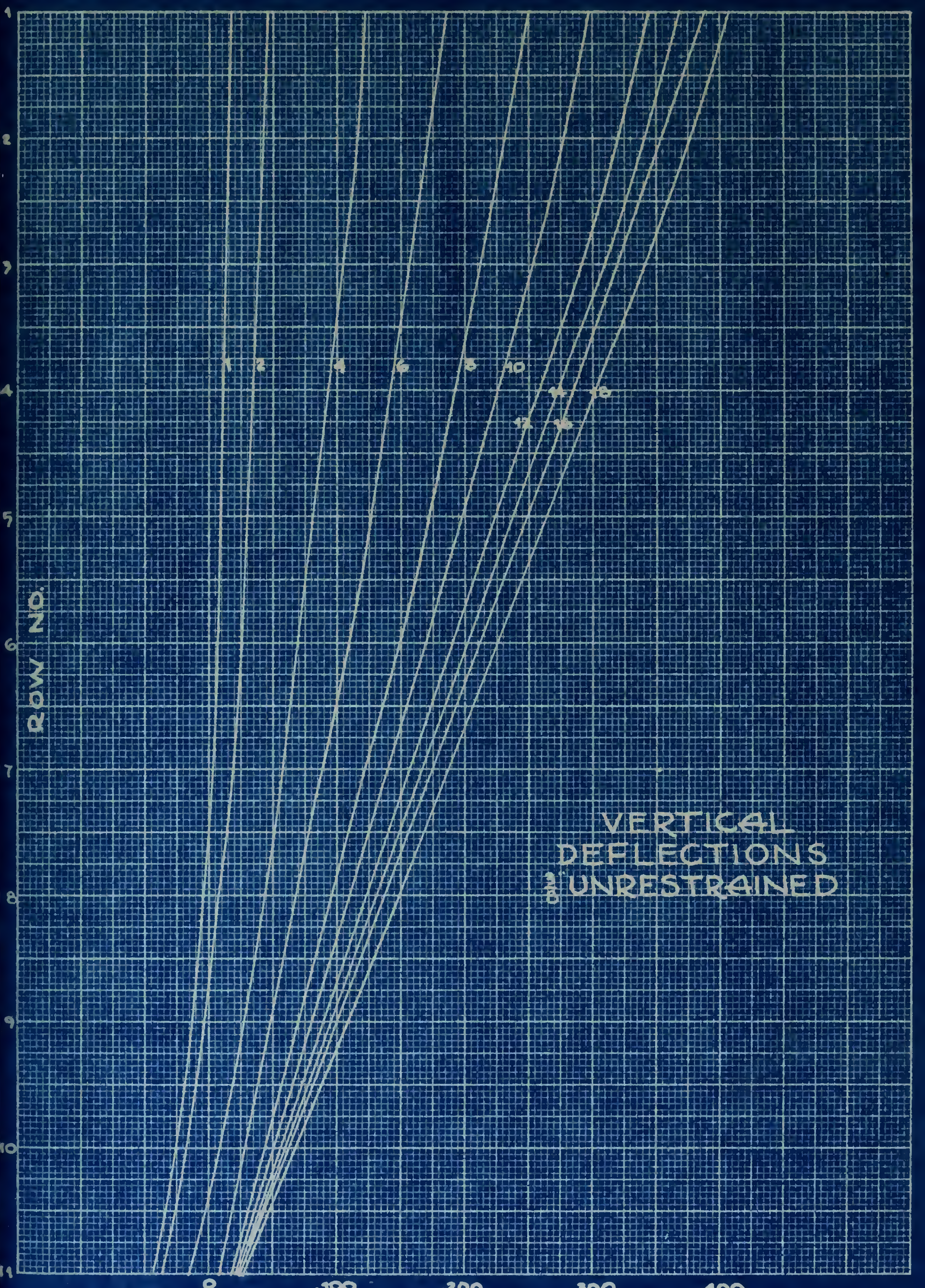
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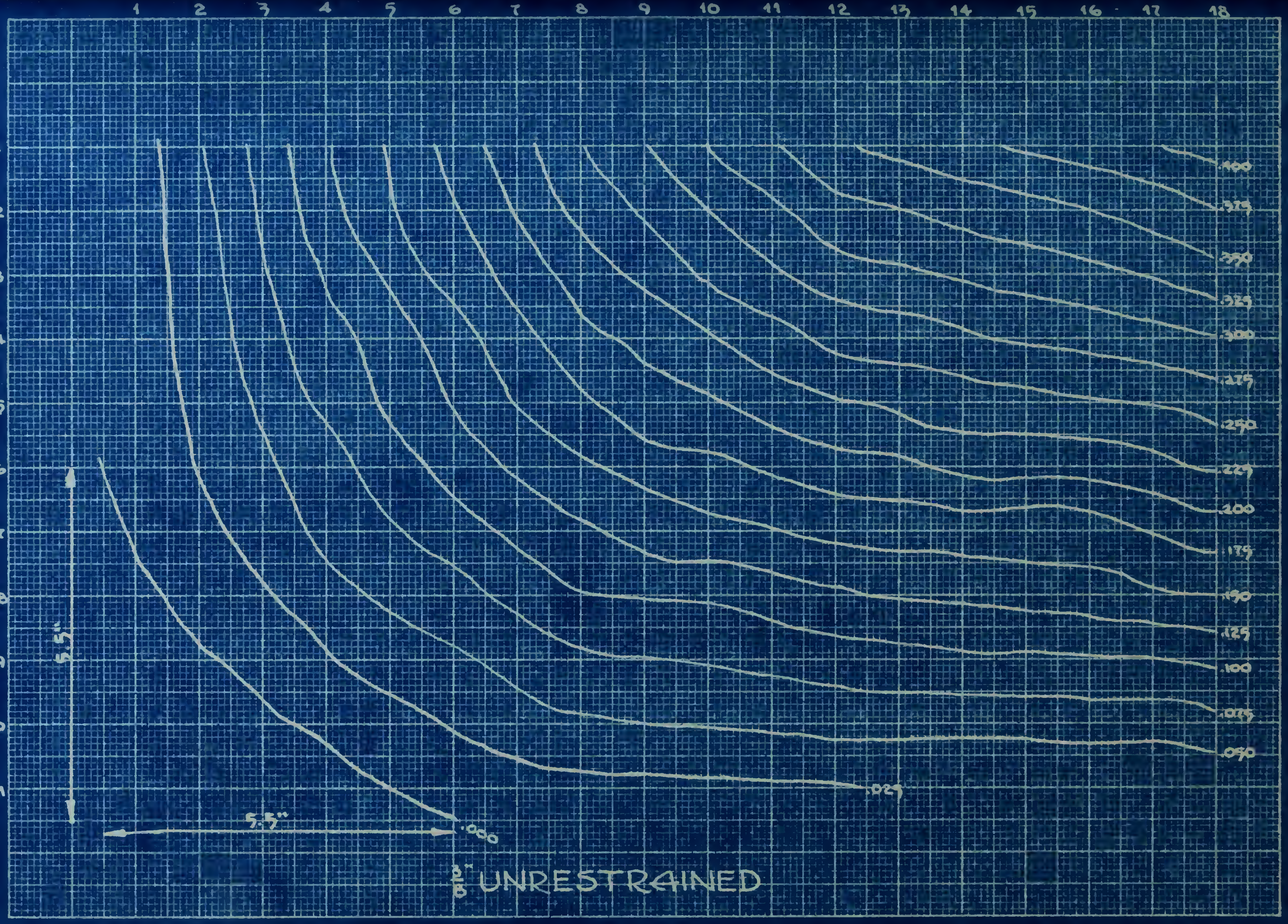

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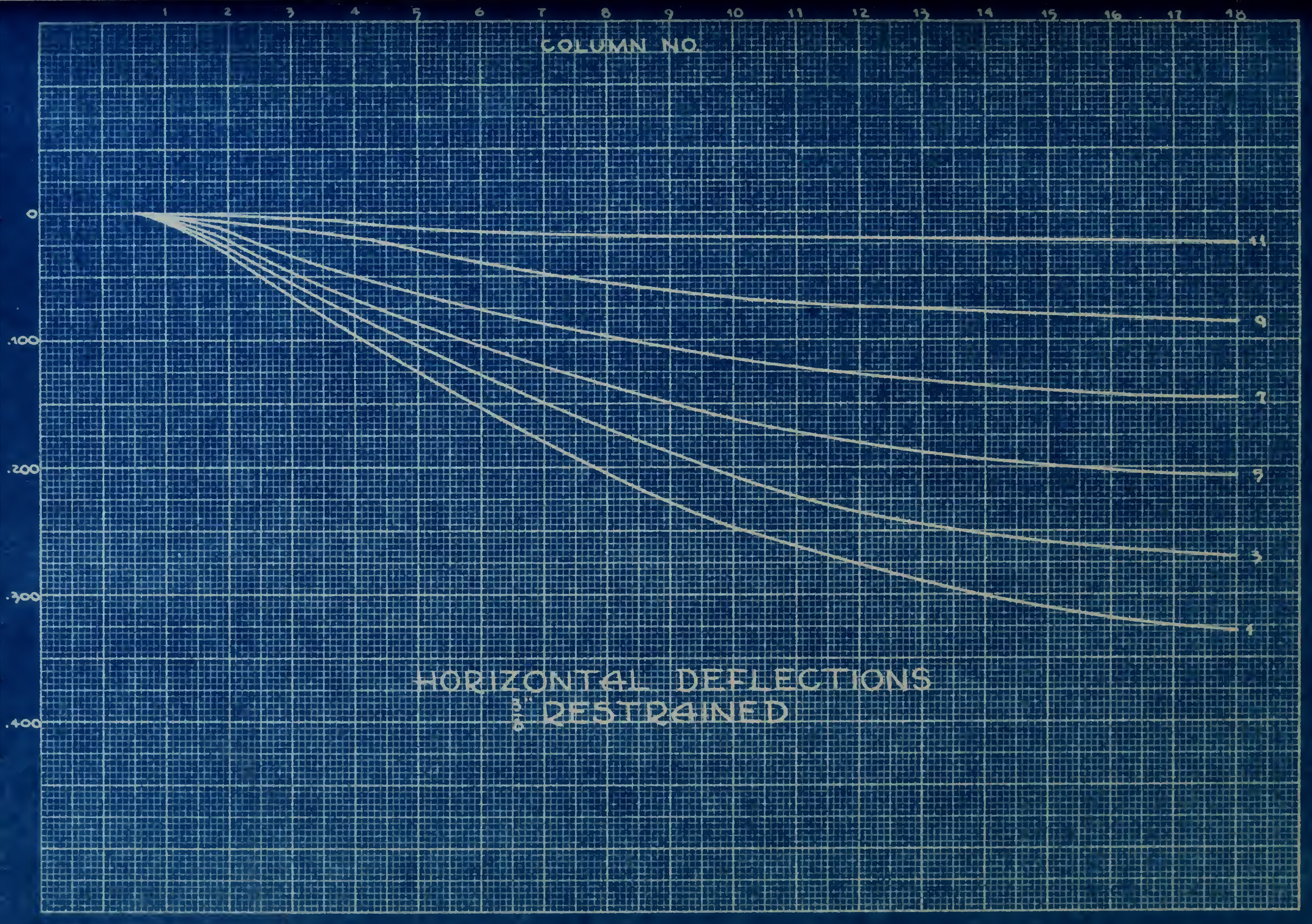
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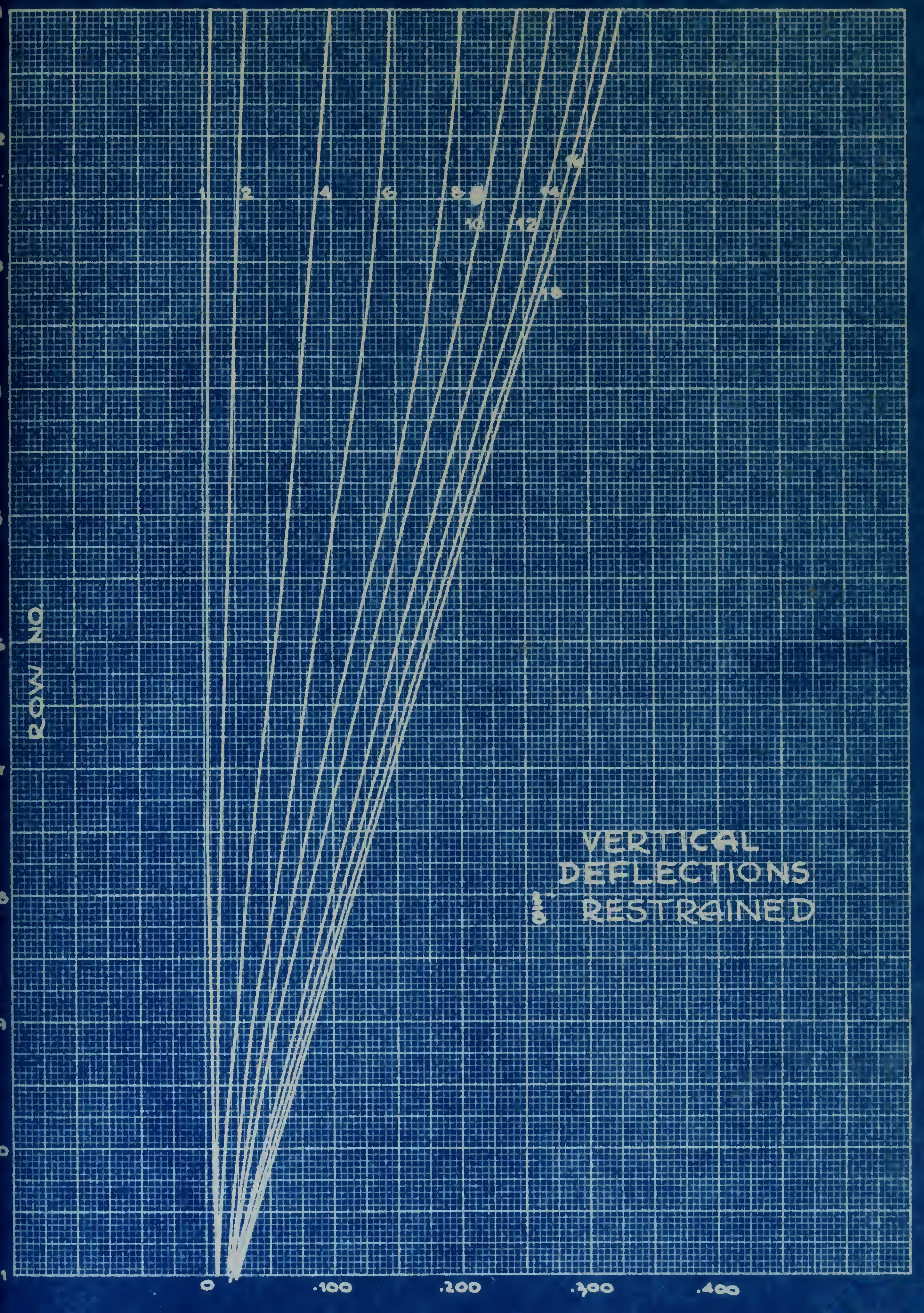
3/16" RESTRAINED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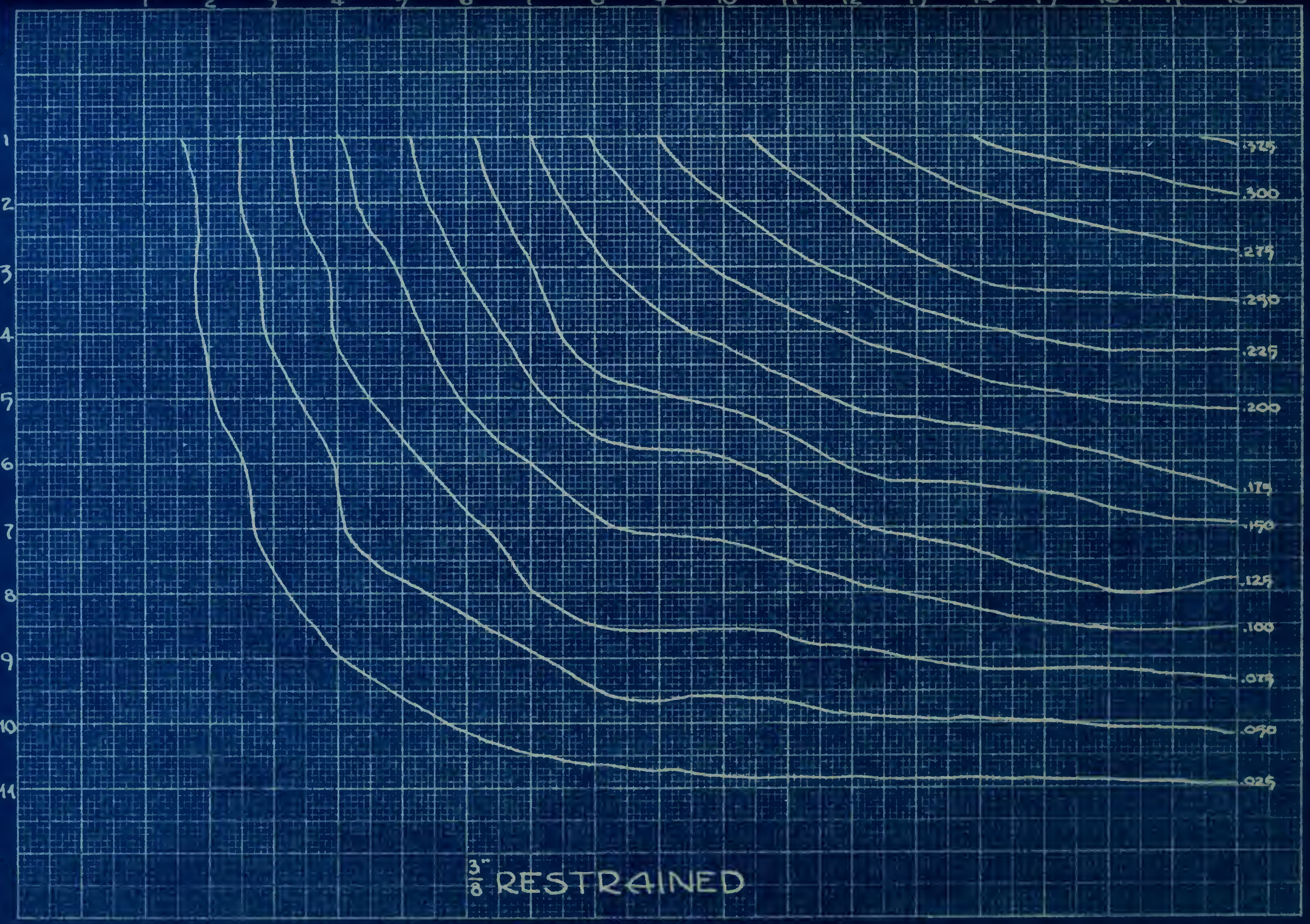

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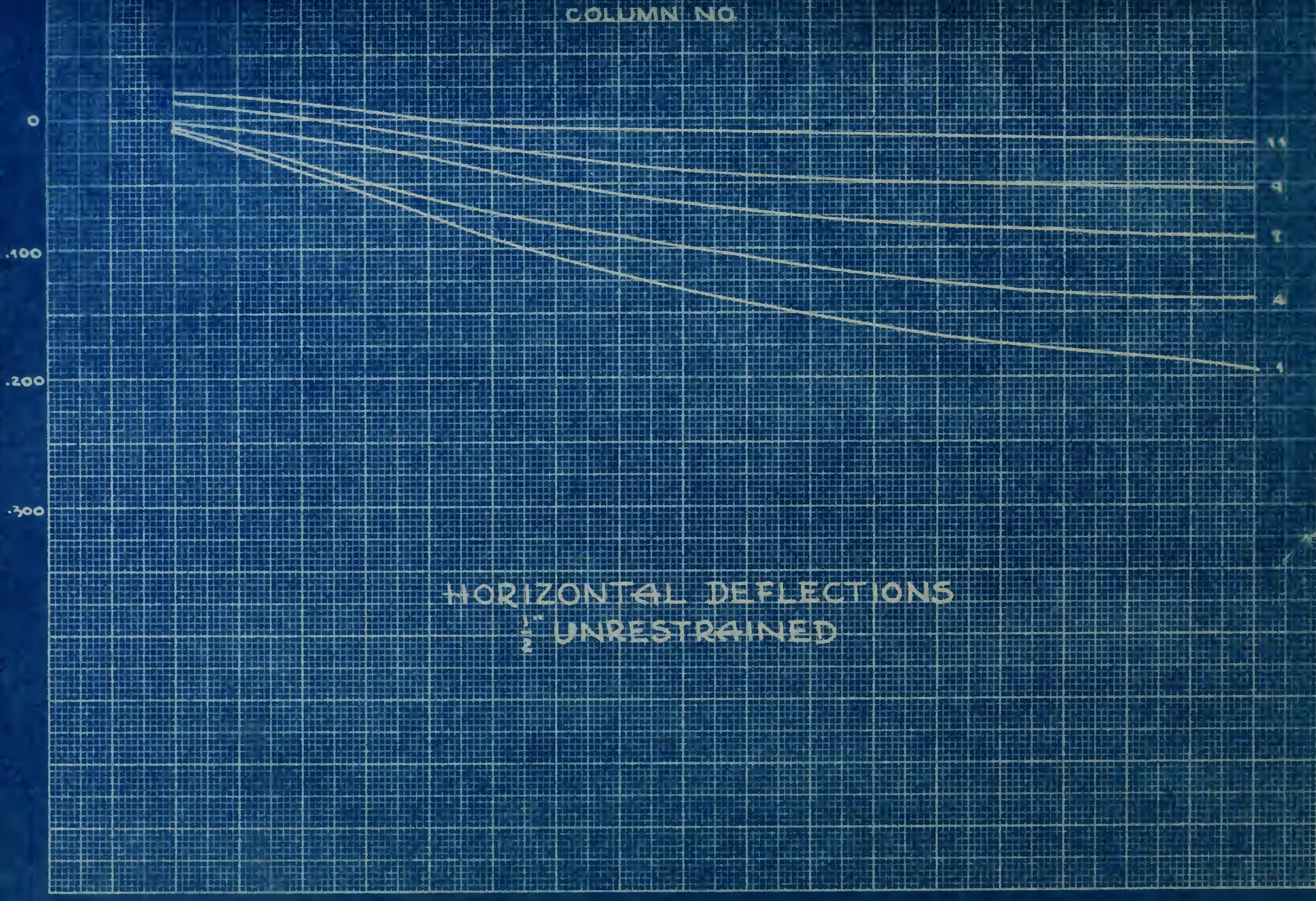
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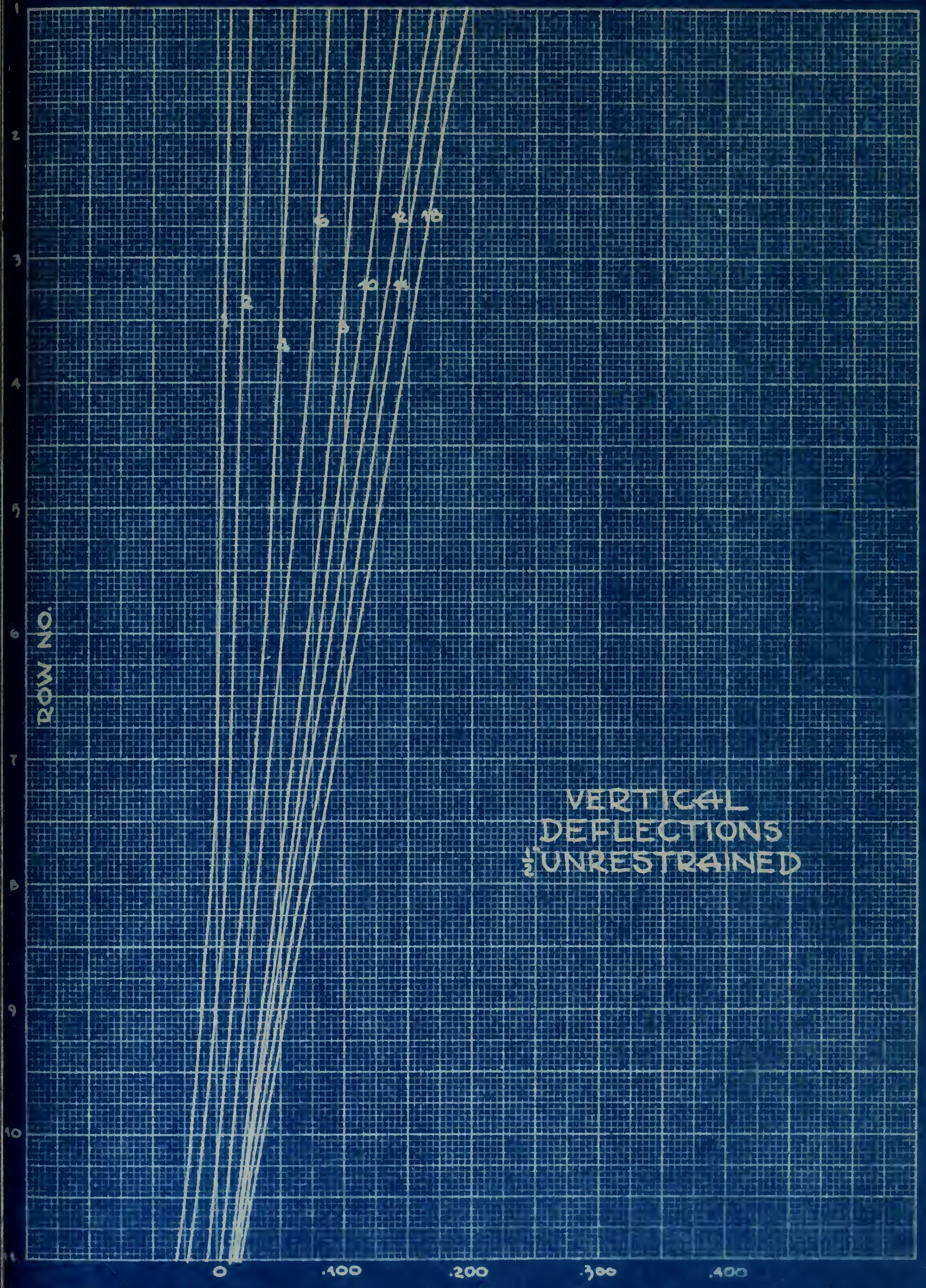

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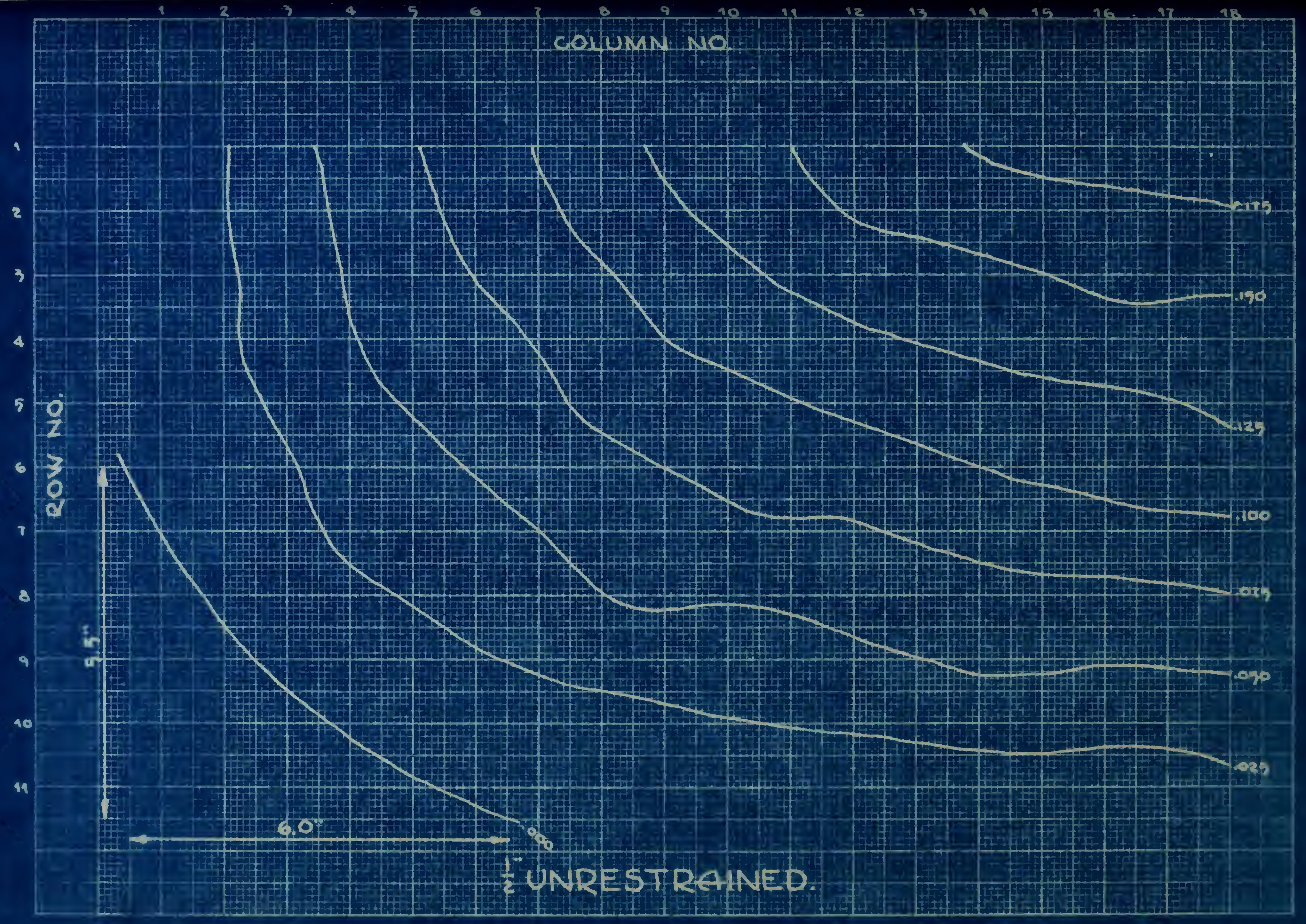

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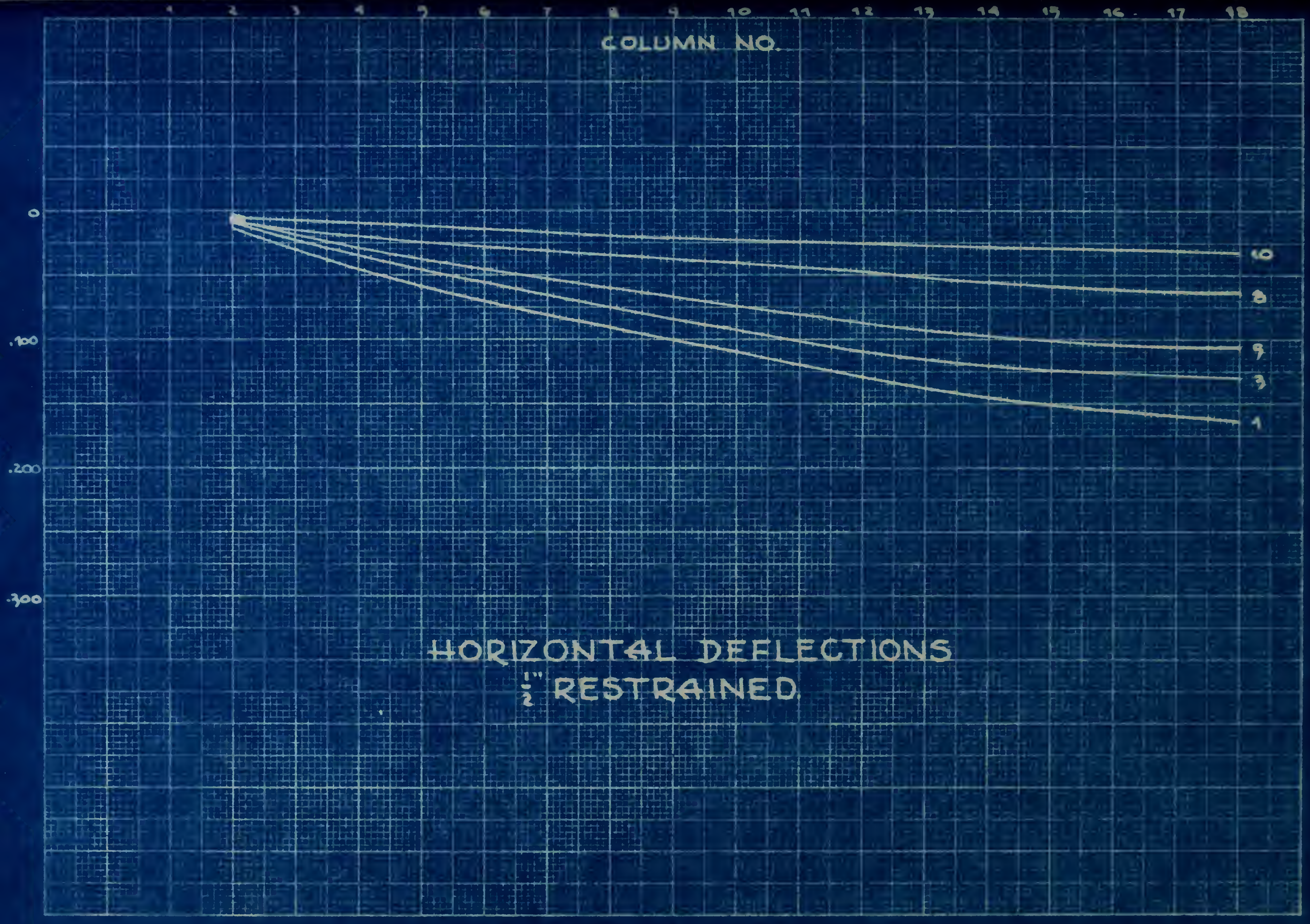

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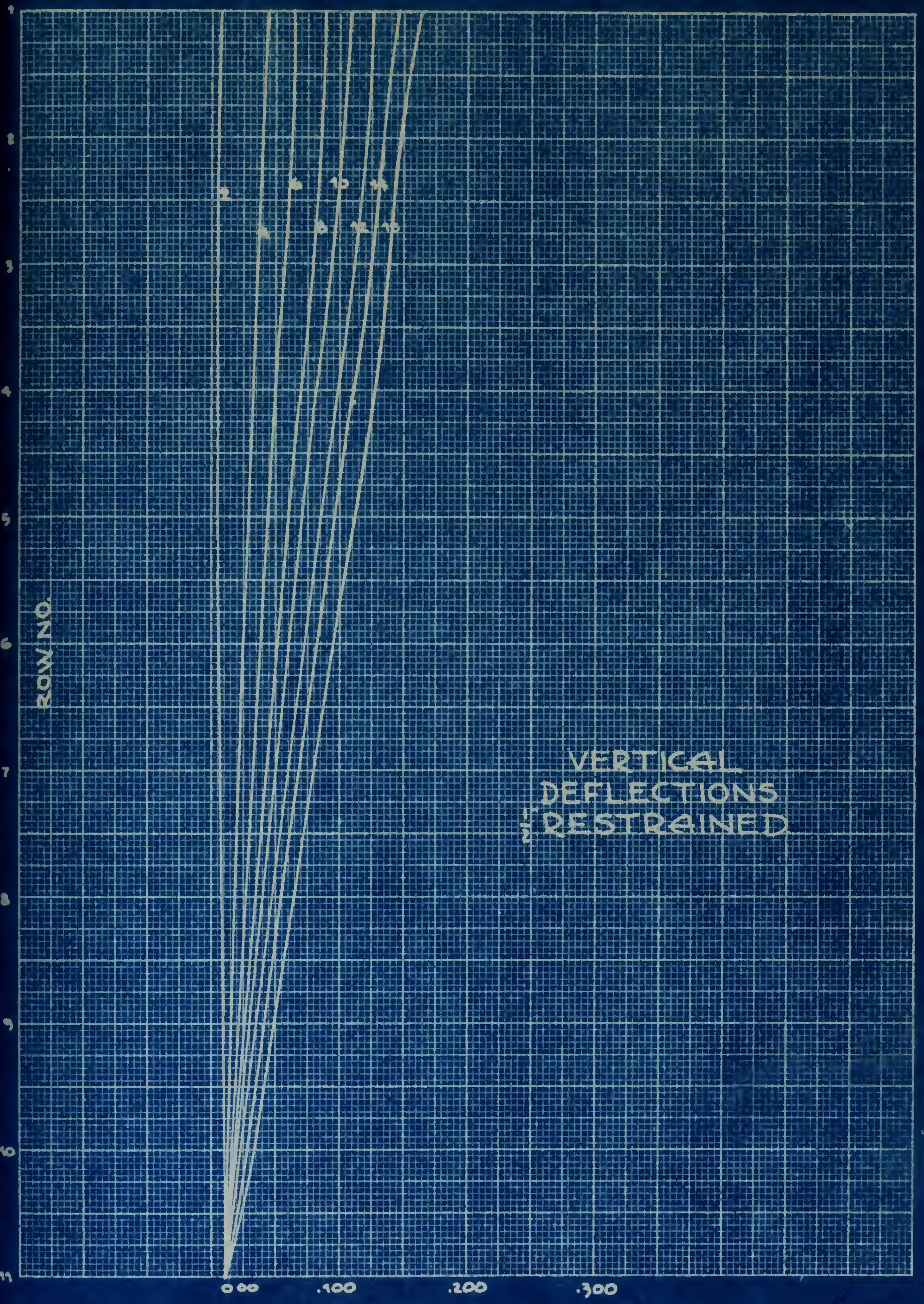2
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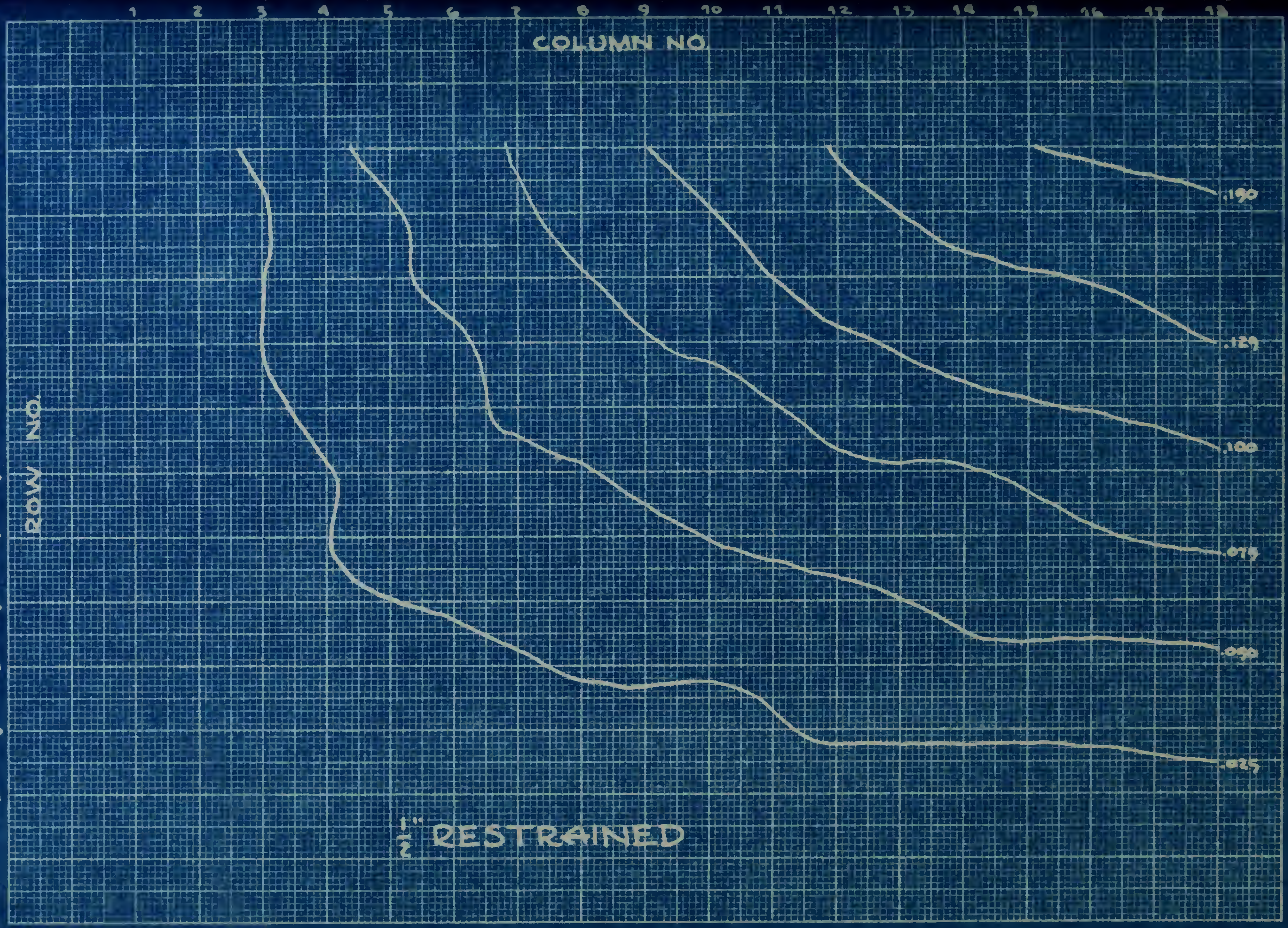
VERTICAL
DEFLECTIONS
½ RESTRAINED



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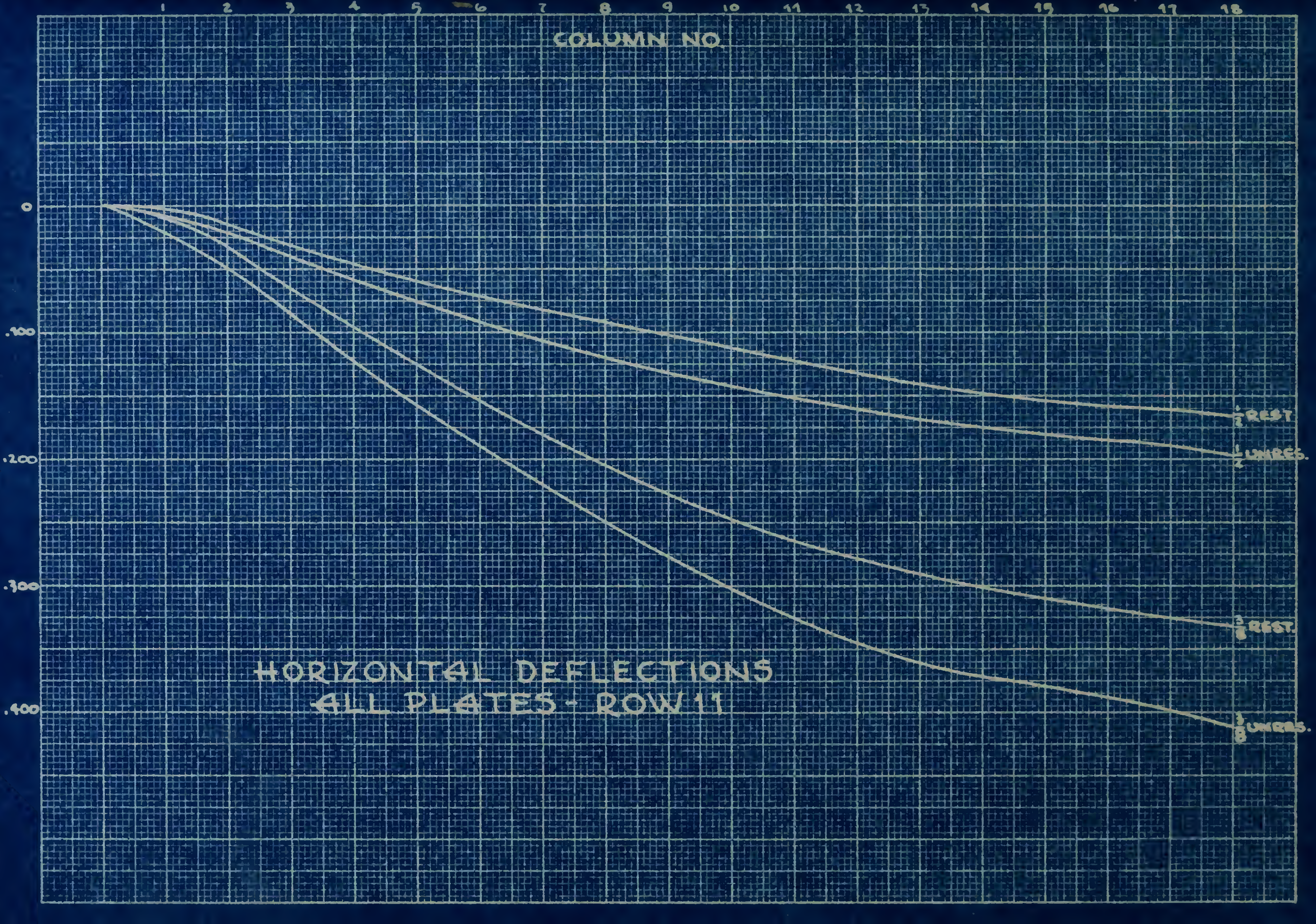
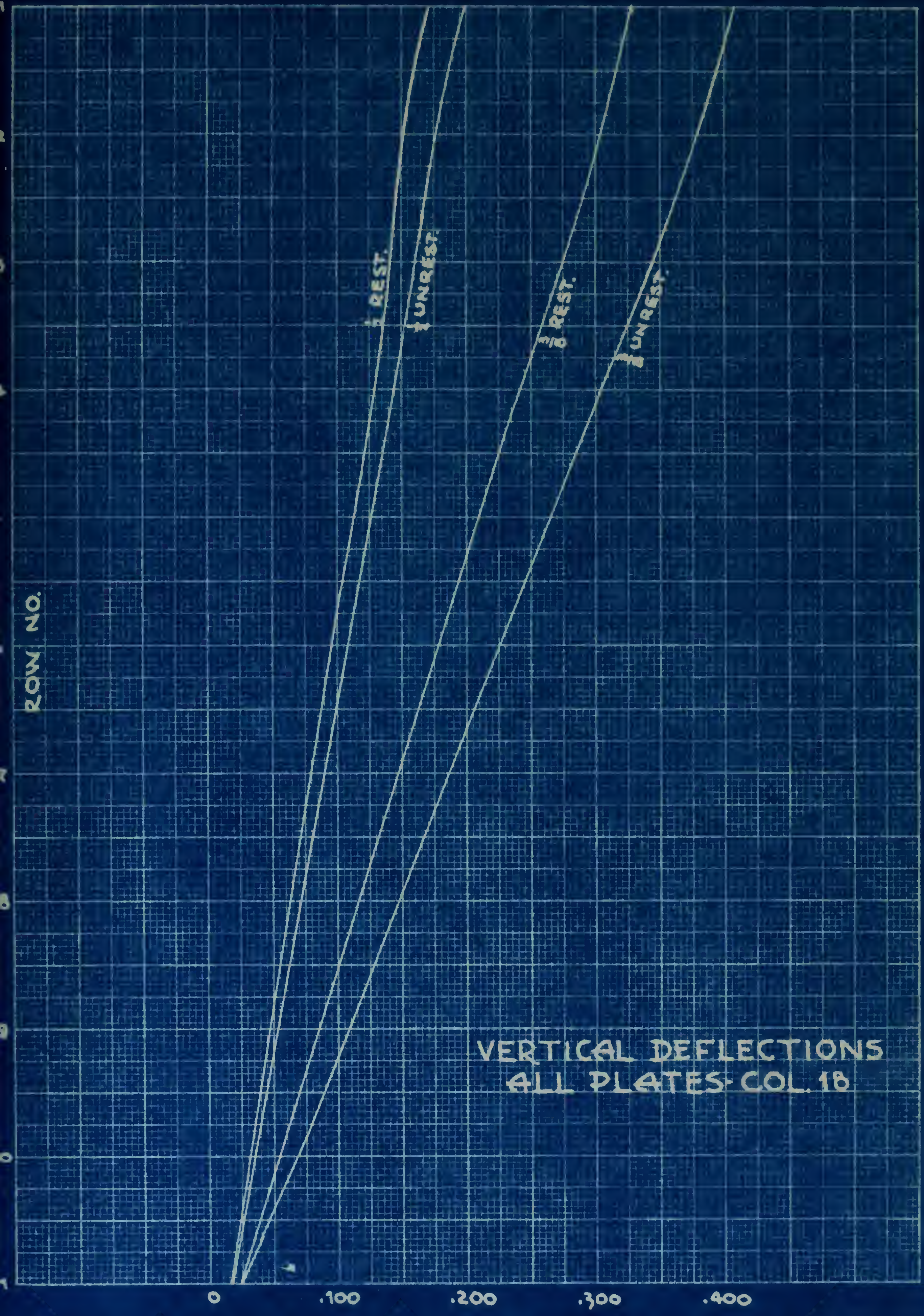


HORIZONTAL DEFLECTIONS
ALL PLATES - ROW 11



VERTICAL DEFLECTIONS
ALL PLATES-COL. 18

DATE DUE

Thesis
L75 Livingstone 7478
AUTHOR

Effect upon the deflection pattern
TITLE of restraining the lower corners
of a plate that is simply supporte

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Effect upon the deflection pattern of re
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DUDLEY KNOX LIBRARY